antecedence for the terms in question.

Reconsideration and withdrawal of the rejection of claim 1 under 35 U.S.C. 102(b) as being anticipated by U.S. patent 4,947,074 to Suzuki is respectfully requested. Claim 1 has been amended by incorporating therein the features of claim 2 so that this rejection no longer applies.

Reconsideration and withdrawal of the rejection of claims 2 and 3 under 35 U.S.C. 103(a) as being unpatentable over U.S. patent 4,947,074 to Suzuki in view of U.S. patent 4,973,876 to Roberts is respectfully requested.

Reconsideration and withdrawal of the rejection of claim 4 under 35 U.S.C. 103(a) as being unpatentable over U.S. patent 4,947,074 to Suzuki in view of U.S. patent 4,973,876 to Roberts and further in view of U.S. patent 5,017,010 to Mamin et al. is respectfully requested.

Reconsideration and withdrawal of the rejection of claim 5 under 35 U.S.C. 103(a) as being unpatentable over U.S. patent 4,947,074 to Suzuki in view of U.S. patent 4,973,876 to Roberts and further in view of common knowledge in the art is respectfully requested.

According to amended claim 1 of the present invention, the clocked switches are arranged in a half bridge and are provided in the form of MOS transistors, wherein an external diode is series-connected to the switching path. This series connection is bridged by a commutating diode which is poled opposite to the external diode.

Another principal idea of the present invention is expressed in claim 6 and resides in a circuit configuration for dynamic control of piezotranslators (ceramic solid-state actuators) with energy recovery. The energy recovery is realized by a single inductive intermediate storage series-connected with the piezotranslator. According to the invention, the clocked switches are positioned in a half-bridge wherein for obtaining the predetermined linear voltage course at the piezotranslator, a current control with a current sensor controls the clocked switches of the half-bridge with high cycle or switching frequency. Moreover, a position control is superimposed on the current control.

Fig. 1 of Suzuki shows a certain charging circuit (battery 1, transistor 3, and piezo element 2) which charging circuit is separate from the discharge circuit.

For the charging phase the charging circuit includes no reactive element at all. If switch 3 closes, the piezo element 2 will be immediately and fully charged to the peak value of the battery 1. The power efficiency during this charging phase cannot be improved by any switching action of the switch 3 because there is no energy store available in this path. On the other hand, the switch 3 will always dissipate the same amount of power during the charge cycle which is equal to the power finally stored in the piezo element 2 after the charging phase is complete. This is due to the internal switch resistance of the transistor 3 and thus reduces the charging efficiency to a maximum value of 50%.

The discharge circuit consists of the piezo element 2, intermediate inductive store 53, and switches 6a, 7a. The switches 6a, 7a do not form a half-bridge configuration. A half bridge configuration uses two switches, one being connected to one supply (or ground) and the other connected to another (different) supply. The Suzuki circuit uses two switches but they are connected both in parallel and connected both to the same potential (GND).

The configuration of Suzuki is such that the circuit will improve the power efficiency only during the discharge cycle.

During the charging interval, neither switch 6a nor 6b can provide a controlled charging function because neither of these switches is connected to the power supply 1.

In regard to a controlled charging or discharging action for achieving a predetermined voltage characteristic on the piezo element 2, applicant submits that the switch 3 allows charging only to the full maximum value of the battery 1. Stopping at a predetermined value of piezo voltage is not possible. No predetermined linear voltage characteristic is given during ramp-up. Furthermore, charging to the full value of the battery 1 is always dissipative. The switches 6a, 7a allow discharge of piezo element 2 only in the following way: down to the negative equivalent of the voltage value at the beginning of discharge.

The discharge mode works only in close connection with the natural resonance frequency determined by the inductivity (L) of the store 53 and the capacitance (C) of the piezo element 2. This is clearly illustrated in Fig. 2 of Suzuki.

The obtainable time function is predetermined by those fixed L/C parameters. There is no means for speeding up or delaying this time function by any additional switching action of the switches 6a, 7a and therefore there is no possibility of

correlating this function to any externally predetermined voltage characteristic.

Even when the switches 6a, 7a are not thyristors (as shown on Fig. 1), but instead devices allowing current switch-off prior to zero crossing, the discharge function cannot be delayed. Any attempt to interrupt one of the switches before reaching its zero crossing point will isolate the stored energy in 5 with the effect that the voltage across 5 will climb to very high values. Because there is no other feedback half available (e.g. from the bottom side of store 53 to the power supply), the residual energy of 5 will be spoiled in a very short period of time, and this will eliminate any power saving during the discharge mode.

Even if one power supply, one piezo element, one storage inductor, and two or three switches are employed, the arrangement according to Suzuki according to Fig. 1 is not comparable to the configuration of the present invention. Especially in the path which connects the piezo element 2 to the power supply 1 no intermediate storage element is provided in Suzuki.

Firstly, this restricts the power efficiency improvements only to the discharging cycle, wasting 50% of the power, and secondly restricts the full power saving feature achievable

during discharge mode only to the "negative voltage recharge point" (or to the "zero voltage discharge point" described in the present invention). All other discharge levels result in loss of the residual energy.

Coupling the voltage-time function of the piezo element 2 to a predetermined linear voltage characteristic (other than the proposed full swing action needed in the ink jet driver of Suzuki) is not possible because the Suzuki design allows charging only to the full supply voltage. Furthermore, any attempt to control at least the discharge portion will end in losing fractions of, or all, power savings possible during discharge.

The inventive configuration is designed for use in linear amplifiers. The arrangement of the piezo element, the intermediate store, and the switches is different from that of Suzuki. In particular, the storage element according to the invention is available in the path which connects the piezo element to the power supply.

In contrast to Suzuki, the present invention at all times provides full control of the voltage-time function of the piezo element, even during charging of the piezo element, and also allows small fractional voltage steps. Moreover, this is

possible fully symmetrically.

During all charging and discharging phases, either fractional or full amplitude, the half bridge configuration provides full energy saving factors of theoretically 100%.

The cited prior art reference to Suzuki et al. does not show a half-bridge circuit either in Fig. 1 or in Fig. 4. Moreover, the series connection of the piezo translator and intermediate store is not constantly supplied with direct bridge current during the active state which is modulated by a high-frequency alternating current with a relatively small amplitude. Neither does Roberts show such an arrangement.

It is moreover respectfully submitted that the coil which is arranged upstream of a piezo actuator forms a resonance circuit together with the own capacitance of the piezo actuator. In all piezo motor drives the total arrangement is operated, for obtaining an optimal overall efficiency, only with this resonance frequency or a frequency directly adjacent thereto.

The magnitude of the coil inductivity determines this working frequency which is the only frequency that is suitable. The resonance is desirable and results in a substantially higher

alternating voltage at the piezo element and thus in an improved efficiency.

The half bridge configuration arranged upstream of the coil is supplied alternatingly for this purpose with rectangular pulses having precisely this resonance frequency. For obtaining a reduced amplitude at the motor, the pulse width is reduced. The upper and lower pulses however always have identical pulse width. The coil combines these individual pulses again to a half wave occurring at the piezo element because operation is always within or near the resonance frequency.

All known control arrangements relate exclusively and particularly to the exact generation of this working frequency identical to the resonance and are provided for generating a very small but important frequency shift to somewhat greater frequency values for compensation of the stability problems resulting from the use of a piezo element. These known coils are often referred to as pulse shaping means. None of the prior art references cited in the office action discloses that the coil, for reasons of energy storage or recovery, is to be used for charging as well as discharging of the piezo capacitance.

Accordingly, a modulation of the half bridge in the sense of

an asymmetric pulse length is also not suggested.

The working frequency of the piezo transformer according to the present invention is within a working range beginning at 0 up to an upper limit as large as possible. This upper limit is determined by the mechanical own resonance of the complete arrangement of the piezo element and the workpiece connected thereto. Up to this upper limit, an operation as uniform as possible of the entire arrangement is to be provided.

The coil according to the present invention - referred to as intermediate store - generates for physical reasons with the own capacitance of the piezotranslator again a further resonance. This "electronic" resonance in many situations is below or near the mechanical resonance, i.e., still possibly within the desired working range. However, its occurrence is highly undesirable because this frequency, out of the total working frequency range, will be particularly enhanced and its amplitude is increased in an undesirable way.

The linear correlation between the path deflection and the applied control voltage to be obtained with the arrangement is impermissibly falsified in the case of this electronic resonance within the dynamic range.

However, this fact casts doubt on the principal usefulness of the circuit arrangement examined particularly for the purpose of energy savings because of the determined electronic resonance. However, the precise value of the working frequency of the half bridge according to the invention is significantly greater. It is at least one magnitude greater than the two mentioned electronic and mechanical resonances. Accordingly, the effect of the inventively provided coils in comparison to the prior art references cited in the office action is completely different.

The precise value of the working frequency is generally unimportant and no control is provided here. The half bridge pulses are modulated with asymmetric pulse width according to the cycle of the low-frequency modulation. The coil has, in addition to its function as an energy store means, the object to keep the high working frequency away from the piezo element and not to enhance it with resonance. This is achieved by a large spacing of the high working frequency from the resonance. The participating controls, whose input values are again voltage and current at the piezo element, are provided for different purposes than those described in the cited prior art references. In particular, in contrast to the prior art references, suppression of the electronic resonance as much as possible is to be achieved, for which purpose the current control is provided.

In regard to the MOS transistors with external diodes, it should be noted that especially in operation with very high working frequencies of the half bridge of 100 kHz to 500 kHz significant losses on the known internal inverse diodes will occur. As demonstrated in experiments, these losses are not caused exclusively by voltage drop occurring at any desired diode but are based on the relatively bad dynamic properties of the internal diode, for example, the blocking delay and the thus resulting relatively slow switching. Avoiding these internal losses is achieved by providing a diode 10 which is poled in the through direction and connected to the switch in a series connection. It has the purpose of providing complete electrical shut-down of the other internal diodes of the MOS transistor exhibiting high losses. This configuration also results in a complete isolation of the entire MOS switch in the blocking operation inclusive of its inverse diode. It was found that the total losses of both additional diodes are below the losses which are present in the case of conventional inverse diodes.

Applicant submits that claim 1 as amended and new claim 6, together with their dependent claims, respectively, are not anticipated or obvious in view of the prior art references, alone or in combination.

Therefore, in view of the foregoing, it is submitted that this application is now in condition for allowance and such allowance is respectfully solicited.

Any additional fees or charges required at this time in connection with the application may be charged to Patent and Trademark Office Deposit Account No. 11-1835.

Respectfully submitted,

Friedrich Kueffner
Reg. No. 29,482
317 Madison Avenue
Suite 910
New York, N.Y. 10017
(212) 986-3114

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Encl.: new claims 6-10; amended claims 1-4 (clean copies and marked-up version); amended paragraphs of pages 1, 5, 10 of the specification (clean copies and marked-up versions); letter to draftsperson with 1 sheet drawing proposal

CERTIFICATE OF MAILING

I hereby certify that this correspondence is being deposited with the United States Postal Service as first class mail in an envelope addressed to: Assistant Commissioner for Patents, Washington, D.C. 20231, on April 24, 2002.

By: ______________________ Date: April 24, 2002
Friedrich Kueffner